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On the movement of a fish-group. IV. The shape of the entrance of fishing net and the fish-group moving in and out.

By

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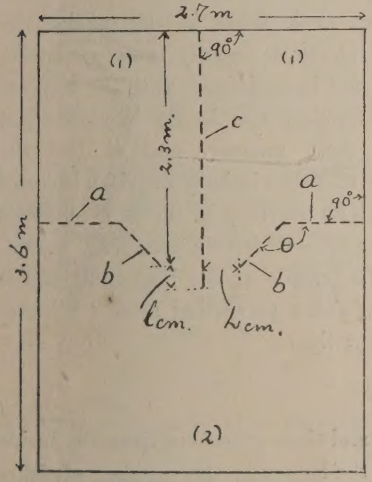
This experiment was done to study the fish-group moving in and out in relation to the shape of entrance of fishing net.

Fishes supplied for this experiment were carp 6～8 cm. long (from head to tail).

Fig. 1.



a: side, *b*: arm, *c*: leading, (1): outside, (2): inside.

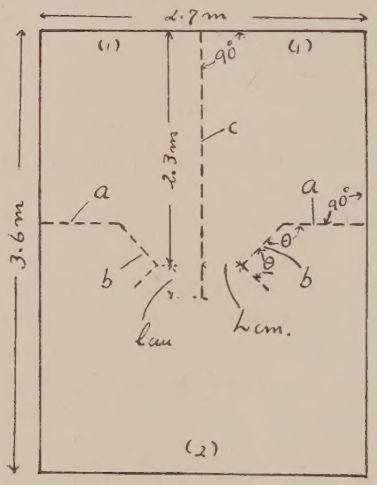
Two side nets (Fig. 1, *a*) were set to project from the opposite longer sides of a pond, $3.6^m \times 2.7^m$, and an arm net (Fig. 1, *b*) was fixed to the distal end of the each side net. The pond was thus divided into two parts by the side and arm nets. One of the two parts was regarded as the inside of fishing net and the other, the outside. The outside and the entrance of fishing net were symmetrically divided by a leading net (Fig. 1, *c*). The leading net was extended in the length of $l_{cm.}$ into the inside beyond the line connecting the free ends of the two arm nets, and the free end of each arm net was kept $L_{cm.}$ apart from the leading net.

On closing the entrance by a net, equal number of fishes was put in two compartments of the outside. After the fishes having got in a calm state the entrance was opened. Then we observed the number of fishes coming in the inside, denote by c.i., that going out, g.o., and that returning to the inside after having reached the entrance, r.t. The observation was done for two consecutive 30-minutes. Fishes were changed experiment after experiment, because their motion became inactive after an hour.

The similar observation was done with an arm net having an angle θ (Fig. 2).

Dividing every 30-minutes into four equal intervals—for the sake of convenience we define this interval as a period—, and counting the number of fishes, c.i., g.o. and r.t. in each period, we get the results given in Table I. The number of fishes in the outside of fishing net at the end of each period can be calculated from c.i., g.o. and the number of fishes put in the outside at the beginning of the experiment. From Table I we see that c.i. is much greater than g.o. in the earlier periods but the difference decreases as the time lapses, and that at last they become to have an equal value. The number of fishes in the outside decreases at first rapidly and gradually slowly, and in accordance with the decrease of the outside, the inside increases just in the same manner, and at last the number of fishes in both the sides becomes fixed. The mark ↓ in Table I indicates the time after which the number is fixed.

Fig. 2.



a: side, *b*: arm, *c*: leading, (1): outside, (2): inside.

Now denote the number of fishes in the outside at the beginning of the experiment by N and denote the number of fishes presenting after t minutes in the outside and inside by n_1 and n_2 resp., then

$$n_1 + n_2 = N$$

If fish-groups coming in to the inside and those going out from the inside are assumed not to meet in the vicinity of the entrance, the number of fishes per unit time coming in to and going out from the inside may be $a_1 n_1$ and

$\alpha_2 n_2$ resp., where α_1 and α_2 are some constants depending on the dimension of the outside and inside, the shape of entrance, and also on the activity of fishes. But, in general, the number of fishes per unit time coming in to and going out from the inside may be represented by $\alpha_1 n_1(1-k\alpha_2 n_2)$ and $\alpha_2 n_2(1-k\alpha_1 n_1)$ resp., where k is a constant depending on the probability of occurrence of meeting and on the effect of attraction of one fish-group on the other.

Therefore $$\frac{dn_1}{dt} = \alpha_2 n_2(1-k\alpha_1 n_1) - \alpha_1 n_1(1-k\alpha_2 n_2)$$
$$= \alpha_2 n_2 - \alpha_1 n_1$$

But $$n_1 + n_2 = N$$

Then $$\frac{dn_1}{dt} = \alpha_2 N - (\alpha_1 + \alpha_2) n_1$$

Integrating the equation, we get

$$n_1 = \frac{\alpha_2}{\alpha_1+\alpha_2} N + Ce^{-(\alpha_1+\alpha_2)t}$$

Since the total fishes were put in the outside at the beginning,

$$n_1 = N \qquad \text{when } t = 0$$

Hence $$C = \frac{\alpha_1}{\alpha_1+\alpha_2} N$$

Therefore $$n_1 = \frac{\alpha_2}{\alpha_1+\alpha_2} N + \frac{\alpha_1}{\alpha_1+\alpha_2} Ne^{-(\alpha_1+\alpha_2)t}$$

Accordingly $$n_2 = \frac{\alpha_1}{\alpha_1+\alpha_2} N(1-e^{-(\alpha_1+\alpha_2)t}) \qquad \text{.....(1)}$$

The equations (1) represent: (i) the number of fishes in the outside decreases as the time goes on, while that in the inside increases and at last they become fixed; (ii) the time, τ, after which the number of fishes in both the sides is fixed, varies inversely as $(\alpha_1+\alpha_2)$.

Denote the number of fishes in the inside and outside after the time, τ, by $\underline{n_2}$ and $\underline{n_1}$ resp., then

$$\alpha_1 \underline{n_1} = \alpha_2 \underline{n_2},$$

because $\frac{dn_1}{dt} = 0$ after the time τ.

Therefore $$\frac{\underline{n_1}}{\underline{n_2}} = \frac{\alpha_2}{\alpha_1} \qquad \text{.....(2)}$$

From Table I, we obtain the time, τ, and the number of fishes after τ, n_1 and n_2, and from the data in Table I we calculate the constants, α_1 and α_2, by the following formulae

$$\alpha_1 = \frac{\text{total number of fishes which came in to the inside before } \tau}{\tau \times \text{mean of the number of fishes in the outside before } \tau}$$

$$\alpha_2 = \frac{\text{total number of fishes which went out from the inside before } \tau}{\tau \times \text{mean of the number of fishes in the inside before } \tau}$$

Those values of τ, n_1, n_2, α_1 and α_2 are given in Table II. The relation between $\frac{n_1}{n_2}$ and $\frac{\alpha_2}{\alpha_1}$ is graphically shown in Fig. 3. From Fig. 3 we know that the equation (2) holds good. The relation between $(\alpha_1+\alpha_2)$ and $\frac{1}{\tau}$ is shown in Fig. 4. Fig. 4 shows that the time, τ, after which the number of fishes in both the sides is fixed, varies inversely as $(\alpha_1+\alpha_2)$.

TABLE II.

		n_1	n_2	α_1	α_2	n_1/n_2	α_2/α_1	τ
I. $L = 36$ cm., $\theta = 135°$	l cm.			min^{-1}	min^{-1}			min.
	−70	256	144	.031	.079	1.78	2.55	52
	−35	244	156	.036	.055	1.56	1.53	30
	−25	105	125	.119	.115	.84	.97	14
	0	107	293	.074	.069	.37	.93	52
	35	124	276	.109	.065	.45	.60	22
	70	130	270	.150	.146	.48	.97	30
II. $l = 0$, $\theta = 135°$	L cm.							
	8	197	203	.041	.013	.97	.32	22
	16	121	279	.067	.038	.43	.57	30
	26	154	246	.039	.022	.63	.56	44
	30	65	335	.134	.048	.19	.36	30
	46	162	238	.050	.025	.68	.50	22
	56	230	170	.037	.064	1.35	1.73	44
III. $l = 0$, $L = 30$ cm.	θ							
	90°	200	200	.045	.029	1.00	.64	22
	112	164	236	.035	.024	.70	.69	52
	135	70	160	.183	.074	.44	.40	14
	145	145	255	.045	.021	.57	.47	37
	157	243	157	.057	.116	1.55	2.04	30
IV. $l = 0$, $L = 30$ cm.,	θ							
$\theta = 135°$	45°	49	181	.328	.165	.27	.50	7
	90	85	145	.128	.130	.59	1.02	30
	135	69	161	.375	.317	.43	.85	7

Table I.

c.i.....Number of fishes coming in to the inside; *g.o.*....Number of fishes going out from the inside; *r.t.*....Number of fishes returning to the inside after having reached the entrance; n_1...Number of fishes presenting in the outside.

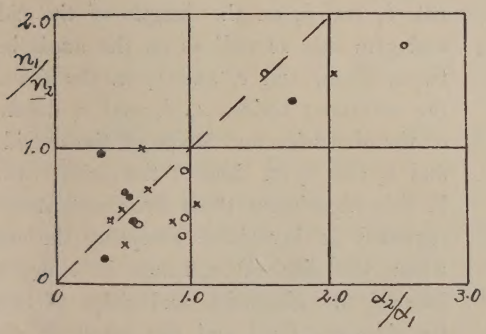
			Period	I	II	III	IV	V	VI	VII	VIII
I. side net 71 cm., arm net 45 cm., L=36 cm., ϑ=135°.	$l_{cm.}$ −70		*c.i.*	135	98	32	44	55	55	86	45
			g.o.	72	72	43	28	37	44	63	49
			r.t.	8	43	4	2	1	6	4	5
			n_1	400	337	311	322	306	288	277	254	258
	−35		*c.i.*	142	80	53	46	37	45	90	70
			g.o.	62	45	29	27	43	40	58	75
			r.t.	7	23	13	12	11	11	9	9
			n_1	400	320	285	261	242	248	243	241	246
	−25		*c.i.*	159	92	40	5	14	19	19	20
			g.o.	47	80	24	24	14	8	30	23
			r.t.	23	17	6	5	1	7	4	3
			n_1	230	118	106	90	109	109	98	109	112
	0		*c.i.*	152	182	94	78	162	123	99	121
			g.o.	80	95	111	49	85	122	54	123
			r.t.	23	49	30	11	16	37	31	77
			n_1	400	328	241	258	229	152	151	106	108
	35		*c.i.*	301	143	84	94	69	42	49	54
			g.o.	120	60	76	79	71	58	40	67
			r.t.	103	13	58	16	47	33	11	43
			n_1	400	219	136	128	113	115	131	122	135
	70		*c.i.*	282	423	155	162	151	116	86	60
			g.o.	170	299	135	155	147	102	98	59
			r.t.	113	209	80	104	57	28	31	44
			n_1	400	288	164	144	137	133	119	131	130

				Period	I	II	III	IV	V	VI	VII	VIII
II. arm net 45 cm., l=0, ϑ=135°.	side net cm. 99	$L_{cm.}$ 8		*c.i.*	139	51	54	19	53	19	36	45
				g.o.	7	20	8	10	34	56	67	30
				r.t.	28	39	76	123	121	88	84	71
				n_1	400	268	237	191	182	163	200	231	216
	91	16		*c.i.*	143	94	86	153	21	59	35	14
				g.o.	14	41	62	67	41	51	38	19
				r.t.	33	61	51	139	22	27	24	17
				n_1	400	271	218	194	108	128	120	123	128
	81	26		*c.i.*	114	108	85	30	31	33	26	22
				g.o.	37	33	19	22	30	17	23	19
				r.t.	57	42	44	17	12	12	39	28
				n_1	400	323	248	182	174	173	157	154	151
	77	30		*c.i.*	349	147	82	102	21	15	30	57
				g.o.	152	43	73	65	24	28	40	47
				r.t.	214	204	81	67	35	30	30	15
				n_1	400	203	99	90	53	56	69	79	69
	61	46		*c.i.*	123	75	103	35	31	61	10	34
				g.o.	32	12	23	24	62	30	28	29
				r.t.	46	15	9	24	15	9	3	7
				n_1	400	304	241	161	150	181	150	168	163
	51	56		*c.i.*	189	87	72	55	44	28	38	13
				g.o.	104	69	40	58	28	12	19	33
				r.t.	183	71	26	56	53	7	27	12
				n_1	400	315	297	265	268	252	236	217	237

					Period	I	II	III	IV	V	VI	VII	VIII
III. l=0	side net cm.	arm net cm.	ϑ										
L=30	107	31	90°		*c.i.*	153	69	54	63	12	26	23	12
					g.o.	30	33	15	68	15	16	8	20
					r.t.	30	93	26	108	16	39	25	33
					n_1	400	277	241	202	207	210	200	185	193
	94	34	112		*c.i.*	137	103	77	42	27	33	21	19
					g.o.	49	52	31	21	20	21	11	18
					r.t.	32	53	37	27	21	18	11	10
					n_1	400	312	261	215	194	187	175	165	164
	74	45	135		*c.i.*	228	74	23	37	27	35	20	7
					g.o.	77	39	29	54	60	12	16	12
					r.t.	152	84	45	35	4	6	7	8
					n_1	230	79	44	50	67	100	77	73	78
	61	55	145		*c.i.*	144	111	30	72	27	10	18	11
					g.o.	27	32	27	24	19	9	14	15
					r.t.	30	48	18	17	15	12	8	10
					n_1	400	283	204	201	153	145	144	140	144
	33	79	157		*c.i.*	212	131	63	107	41	39	23	15
					g.o.	101	125	75	46	58	30	26	14
					r.t.	93	38	27	30	12	12	4	1
					n_1	400	289	283	295	234	251	242	245	244

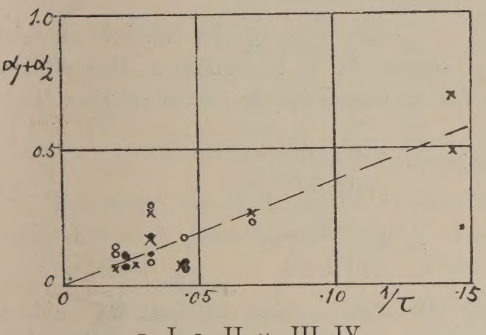
			Period	I	II	III	IV	V	VI	VII	VIII
IV. side net 74 cm., arm net 45 cm + 20 cm., l=0, L=30 cm., ϑ=135°.	ϑ 45°		*c.i.*	305	103	39	36	3	7	4	25
			g.o.	112	102	39	53	12	6	9	8
			r.t.	375	157	93	67	46	8	23	19
			n_1	230	37	36	36	53	62	59	64	47
	90		*c.i.*	243	119	22	134	36	22	49	7
			g.o.	126	111	64	68	46	38	15	7
			r.t.	414	484	70	150	112	67	44	31
			n_1	230	113	105	147	81	91	107	73	73
	135		*c.i.*	370	77	15	48	35	40	18	16
			g.o.	193	91	15	47	56	17	27	20
			r.t.	251	206	85	35	130	37	80	34
			n_1	230	53	67	67	66	87	64	73	77

Fig. 3.



○...I, ●...II, ×...III, IV.

Fig. 4.



○...I, ●...II, ×...III, IV.

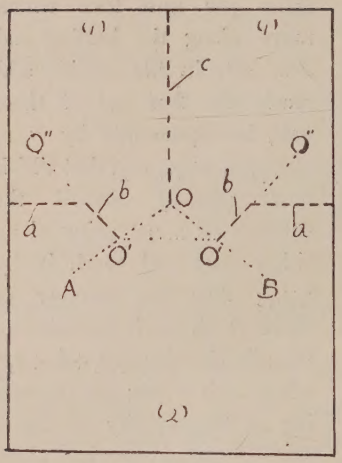
Next, let the number of fishes per unit time which move along the leading and arm nets in the outside and reach the free end of these nets, be represented by $a_1\nu n_1$ and $b_1\nu n_1$ resp., and that which move directly toward the entrance (*i.e.* not going along either net) and reach it, by $c_1\nu n_1$; then the number of fishes which reach the entrance in unit time is $\nu n_1(a_1+b_1+c_1)$, where ν is a constant depending on the activity of fishes. But all fishes moving along the arm net and those moving directly toward the entrance may be considered to come in to the inside, while those moving along the leading net toward the entrance may be considered to get in if they move in any direction between OA and OB (Fig. 5). So, assuming the fraction of the number of all fishes moving along the leading net to its free end, r_1, to move between OA and OB, the number of fishes coming in to the inside in unit time, a_1n_1, is represented by $\nu n_1(a_1r_1+b_1+c_1)$.

Hence $$a_1=(a_1r_1+b_1+c_1)\nu$$

Again, the number of fishes which move in the inside along the arm net and reach its free end in unit time be represented by $b_2\nu n_2$, that of those which move directly toward the entrance and reach it, by $c_2\nu n_2$, and also the fraction, r_2, of the number of fishes moving along the arm net after having passed its free end be assumed to take any direction between $O'O'$ and $O'O''$ (Fig. 5), then the number of fishes which reach the entrance in unit time is $\nu n_2(b_2+c_2)$, and

$$a_2=(b_2r_2+c_2)\nu$$

Fig. 5.



a: side, *b:* arm, *c:* leading.

a_1 depends on the length of the leading net, b_1 and b_2 on the length of the side and arm nets as well as on the angle between them, and c_1 and c_2 on the size of the entrance; besides a_1, b_1 and c_1 depend on the dimension and shape of the outside, and b_2 and c_2 on those of the inside. But in this experiment those five constants are regarded as invariable excepting the case when the size of entrance is changed, because the dimension and shape of both the sides are fixed and the length of the nets and the angle do not vary so much as they have notable influence on the constants.

The ratio of the number of fishes coming in to the inside to that of those reaching the entrance in the outside be named by *the rate of entering*, then

$$\text{rate of entering} = \frac{\nu n_1(a_1 r_1 + b_1 + c_1)}{\nu n_1(a_1 + b_1 + c_1)}$$

$$= \frac{a_1 r_1 + b_1 + c_1}{a_1 + b_1 + c_1}$$

Similarly the ratio of the number of fishes going out from the inside to that of those reaching the entrance in the inside be named by *the rate of leaving*, then

$$\text{rate of leaving} = \frac{\nu n_2(b_2 r_2 + c_2)}{\nu n_2(b_2 + c_2)}$$

$$= \frac{b_2 r_2 + c_2}{b_2 + c_2}$$

But $a_1 = \nu(a_1 r_1 + b_1 + c_1)$ and $a_2 = \nu(b_2 r_2 + c_2)$, then

$$\frac{a_2}{a_1} = \frac{b_2 r_2 + c_2}{a_1 r_1 + b_1 + c_1} = \frac{b_2 + c_2}{a_1 + b_1 + c_1} \frac{\text{rate of leaving}}{\text{rate of entering}}$$

Hence, in all the cases excepting when the size of entrance is changed, the following relation (3) holds

$$\frac{n_1}{n_2} \propto \frac{\text{rate of leaving}}{\text{rate of entering}}, \quad \text{.....(3)}$$

because a_1, b_1, c_1, b_2 and c_2 are fixed, and $\frac{n_1}{n_2} = \frac{a_2}{a_1}$.

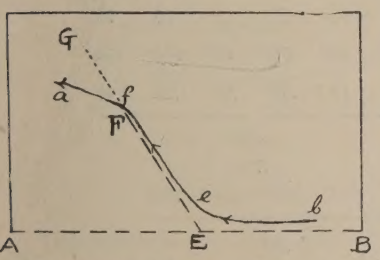
The total number of fishes, g.o. and r.t. in two periods before and after the time τ is calculated from Table I, and the rate of leaving is calculated from the values thus obtained, as it is given in Table III. In this experiment, we did not observe the number of fishes which moved along the leading net to the entrance and went back to the outside without entering the inside, and so we can not calculate the rate of entering from our data of observation.

TABLE III.

I.	$L = 36$ cm. $\theta = 135°$ $l_{cm.}$	−70	−35	−25	0	35	70
	rate of leaving	.92	.75	.82	.62	.68	.65
II.	$l = 0$, $\theta = 135°$ $L_{cm.}$	8	16	26	30	46	56
	rate of leaving	.08	.40	.44	.47	.59	.48
III.	$l = 0$, $L = 30$ cm. $\theta°$	90	112	135	145	157	
	rate of leaving	.38	.58	.34	.51	.71	
IV.	$l = 0$, $L = 30$ cm. $\theta°$	45	90	135			
	$\theta = 135°$ rate of leaving	.29	.30	.38			

Formerly,[1] we set to project a plane net EF from one side AB of a pond or from a plane net AB (Fig. 6), and observed the direction in which a fish-group moves away on passing the free end of the projecting net, F, after having moved along the corner BEF (Fig. 6). From the data of observation in that experiment, we know the frequency distribution of the angle between the direction of movement and the produced line of the projecting net, $\angle Gfa$, for several values of $\angle BEF$ (Fig. 6). Table IV gives the frequency distribution got on carp, 4.5～7.5 cm. long.

Fig. 6.



AEB: one side of pond or a plane net,
EF: a plane net projected from *E*,
FG: produced line of projecting net *EF*,
befa: course of a fish-group.

1) M. TAUTI and H. YASUDA:—On the movement of a fish-group. III. J. Imper. Fish. Inst. XXIV. 2 (1929).

TABLE IV.

Frequency distribution of $\angle Gfa$ (Fig. 6)

	$\angle Gfa$			
$\angle BEF$	0–45	45–90	90–135	135–180
30°	7.4	46.7	43.2	2.9
60	6.7	48.5	44.0	0.9
90	10.4	82.0	7.5	0.0
120	12.2	83.2	4.5	0.0
150	30.0	63.0	6.7	0.3

Fishes moving along the leading net may be considered to enter the inside only when they have less value of $\angle Gfa$[1] than $\tan^{-1}\frac{L}{(-l)}$, where $2L$ is the size of entrance and l is the length of leading net extended into the inside beyond the entrance. Fishes moving along the side and arm nets in the inside may be considered to leave that side only when they have the value of $\angle Gfa$[2] greater than $180°-\theta$ in the case of a straight arm net, and $360°-(\theta+\underline{\theta})$ in the case of an arm net having an angle $\underline{\theta}$, where θ is an angle included between the side and arm nets. The rate of entering, r_1, of fishes which move along the leading net and the rate of leaving, r_2, of fishes which move along the side and arm nets in the inside are calculated from Table IV, as given in Table V.

TABLE V.

I. L=36 cm., θ=135°	$l_{cm.}$	−70	−35	−25	0	35	70
	$\tan^{-1}\frac{L}{(-l)}$	27°	46°	55°	90°	134°	153°
	r_1	.06	.12	.30	.92	1.00	1.00
	$180-\theta$			45°			
	r_2			.79			
III. l=0, L=30 cm.	θ	90°	112°	135°	145°	157°	
	$\tan^{-1}\frac{L}{(-l)}$			90°			
	r_1			.92			

1) $\angle Gfa$ corresponds to the angle included between the produced line of the leading net and the direction in which a fish-group moves on passing the free end of that net.

2) $\angle Gfa$ corresponds to the angle between the produced line of the arm net and the direction in which a fish-group moves on passing the free end of that net.

		$180-\theta$	90°	68°	45°	35°	23°
		r_2	.08	.46	.77	.77	.80
IV.	$l=0$, $L=30$ cm., $\theta=135°$	θ	45°	90°	135°		
		$\tan^{-1}\frac{L}{(-l)}$		90°			
		r_1		.92			
		$360-(\theta+\theta)$	180°	135°	90°		
		r_2	.00	.00	.06		

Comparing Tables III and V, we know that the rate of leaving is about .30 when $r_2 = 0$. Therefore we may assume that 30% of the total number of fishes reaching the entrance have moved directly toward the entrance, one half of the remaining have moved along the leading net and the other half, along the side and arm nets. The rate of entering calculated with r_1 in Table V on this assumption is given in Table VI. $\frac{\text{rate of entering}}{\text{rate of leaving}}$ in Table VI is calculated from the value of the rate of leaving in Table III together with the calculated value of the rate of entering in Table VI.

TABLE VI.

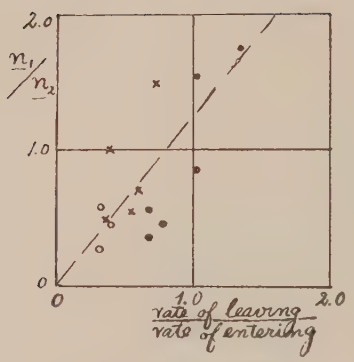
I.	$l_{cm.}$	−70	−35	−25	0	35	70
	rate of entering	.67	.69	.26	.97	1.00	1.00
	$\frac{\text{rate of leaving}}{\text{rate of entering}}$	1.37	1.08	1.08	.64	.68	.65
III.	θ°	90	112	135	145	157	
	rate of entering			.97			
	$\frac{\text{rate of leaving}}{\text{rate of entering}}$	.39	.60	.35	.53	.73	
IV.	θ°	45	90	135			
	rate of entering		.97				
	$\frac{\text{rate of leaving}}{\text{rate of entering}}$	.30	.31	.40			

The equation (3) holds good as seen in Fig. 7 which graphically shows the relation $\frac{n_1}{n_2}$ in Table II and $\frac{\text{rate of leaving}}{\text{rate of entering}}$ in Table VI.

In short, we learn the following results from the present study:

(1) The rate of the coming in of fishes of the outside being given as α_1 and the rate of going out of fishes of the inside, α_2, by the following equations we can estimate the time, τ, after which the number of fishes in both the

Fig. 7.



●...I, ×...III, ○...IV.

sides is fixed and also we can estimate the ratio of the fixed value of number of fishes in the outside, n_1, to that in the inside, n_2,

$$(a_1+a_2)\tau = \text{const.}$$

$$\frac{n_1}{n_2} = \frac{a_2}{a_1}$$

(2) When there is little difference in the dimension and shape of the inside and outside, $\frac{n_1}{n_2}$ can be estimated by the next equation

$$\frac{n_1}{n_2} \propto \frac{\text{rate of leaving the inside of fishes which reached the entrance in that side}}{\text{rate of entering the inside of fishes which reached the entrance in the outside}}$$

(3) The rates of leaving and entering can be calculated from the results of observation of movements of fish-groups in elementary case, as studied in the former experiments. (On the movement of a fish-group I∼III. J. Imper. Fish. Inst. **XXIV. 2,** 1929).

November, 1929.

Physical Laboratory,
Imp. Fisher. Institute, Tôkyô.

Placoid Scales of Five Species of Selachians belonging to Carchariidae.[1]

By

Kiyomatsu Sakamoto.

(Received March 5th, 1930).

The placoid scales of the selachians have been studied by many authors from the view-point of taxonomy; and yet our knowledge of these scales is very meagre. I undertook, therefore, a study of the placoid scales of five species of Japanese selachians, viz., *Cynias manazo*, *Cynias griseus*, *Triakis scyllium*, *Prionace glauca* and *Carcharinus japonicus*, under the direction of Professor Terao. The present paper deals with the scales taken from about a dozen areas of the body surface of the fish, with special reference to their taxonomic value. It is my pleasant duty to return herewith my hearty thanks to Prof. A. Terao for his kindness given me during the course of my study.

Description of the scales.

(1) Cynias manazo (Bleeker) (Fig. 1).

The examined fish measured 55 cm. in length, none of the scales exceeding 0.4 mm. in length. The scales are very compactly set all over the body.

The trunk scales invariably end in a very acute posterior spine, and are provided with two ridges which do not reach the distal end of the posterior spine. These ridges of the scales on the dorsal side of the trunk are more massive and higher than those of the scales on the ventral side of the same (*Da*, *Db*). The scales on the caudal fin (*Qa*, *Qb*) are similar to those on the dorsal and ventral sides of the trunk in general appearance. All the other scales have no ridge and mostly end in a posterior spine which is however absent in the scales on the tongue.

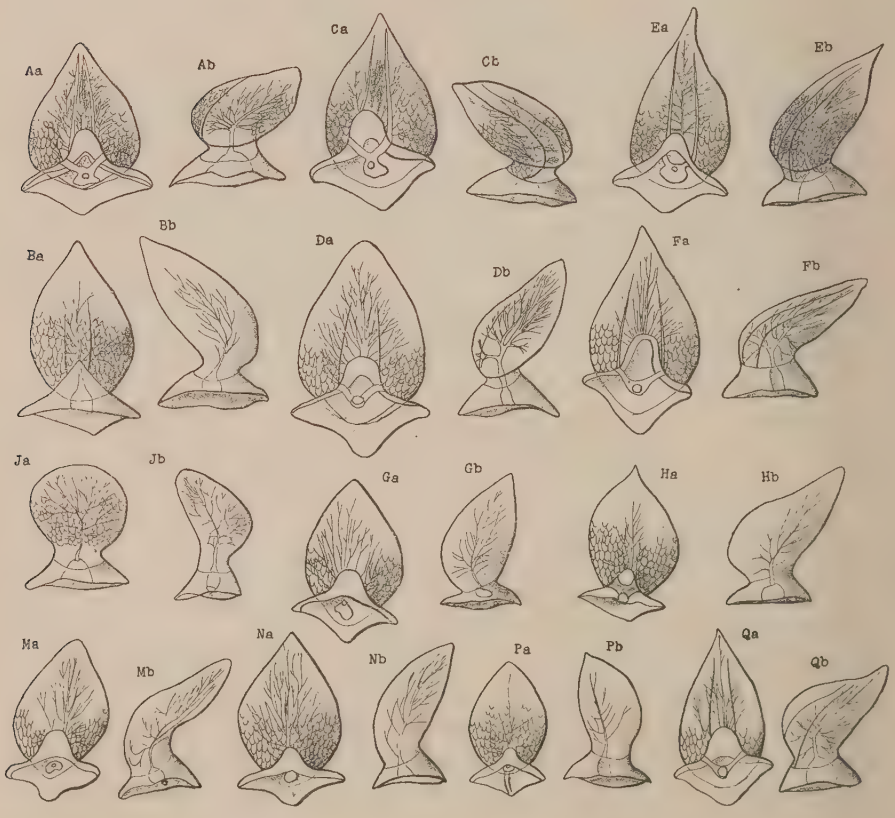
---

1) Contributions from Zoological Laboratory, Imperial Fisheries Institute, No. 5. (No. 4: A. Terao, On the embryonic development of the spiny lobster, Panulirus japonicus. Japanese Jour. Zool. 2 (4): 387–449, 5 *pl.* 1929).

The main body of the scales is longer than wide, but the basal plate of the scales is wider than long. Generally speaking, the height of the basal plate is proportional to the length of the basal plate and of the whole scale, and the width of the basal plate proportional to that of the whole placoid scale.

Fig. 1.

Scales of Cynias manazo, ×60.



A, dorsal side of head; *B*, ventral side of head; *C*, dorsal abdomen; *D*, ventral abdomen; *E*, dorsal caudal peduncle; *F*, ventral caudal peduncle; *G*, first dorsal fin; *H*, second dorsal fin; *I*, pharynx; *J*, tongue; K, gill arch; *L*, opercle; *M*, pectoral fin; *N*, ventral fin; *O*, clasper; *P*, anal fin; *Q*, caudal fin.

The dimension of the scale is the largest in the trunk, larger on the head, and the smallest on the tip of the fins. The measurement is given in Table I. Scaly sculptures are mostly seen on the proximal half of the slightly

Table I. Cynias manazo.

	Main body of the scales.				Basal plate of the scales					
	Length		Width		Length		Width		Height	
	μ		μ		μ		μ		μ	
Dorsal side of head ...	32—34	33	25—27	26	19—23	21	28—31	30	11—16	13
„ „ „ abdome.	34—40	37	23—26	24	18—28	24	25—29	27	8—13	11
„ „ „ caudal ped.	32—41	37	18—24	21	17—23	20	32—28	25	10—12	11
Ventral side of head ...	36—38	37	24—26	25	19—22	20	28—31	30	9—12	10
„ „ „ abdomen	30—40	36	20—29	25	15—22	19	24—30	28	10—12	11
„ „ „ caudal ped.	34—40	37	17—25	21	20—22	21	23—25	24	13—15	14
1st dorsal fin	30—33	31	19—21	20	12—13	12	16—20	18	5— 8	7
2nd dorsal fin	28—34	31	16—21	19	12—18	14	19—23	20	9—11	10
Caudal fin	33—39	36	18—22	21	19—27	24	20—28	25	10—11	11
Pectoral fin.....	25—32	28	16—24	20	15—17	16	17—24	21	7— 9	8
Ventral fin	27—31	29	18—21	19	12—14	13	19—21	20	7—10	8
Anal fin	27—29	28	16—20	18	11—14	12	16—19	18	7—10	8
Tongue	19—23	20	16—22	19	12—17	14	20—23	21	9—13	11

swollen lateral arms of the placoid scale. The main body of the scales is either elliptical, ovoid, or lobed in shape. The basal plate is either rectangular or rhomboidal, with obtuse posterior angle.

Pulpa cavity is small and has no pigment. The pulpa is thickly branched in the scales which are situated on the head, clasper, and in the buccal cavity. The anchoring fibers of connective tissue are mostly very slender and cylindrical in shape and have no branch, but those which are found in the scales on the trunk are comparatively large and give off postero-laterally two branches which reach the margins of the basal plate.

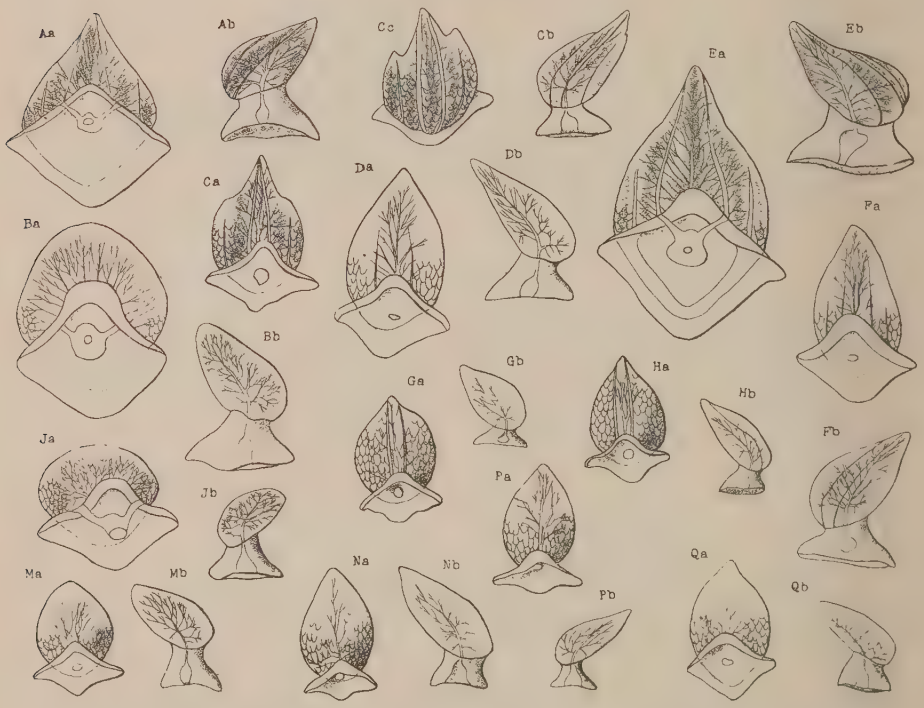
(2) Cynias griseus (Pietschman) (Fig. 2).

The specimen measured 57 cm. long, the scales being less than 0.5 mm.

in length. The scales of the present species resemble those of *C. manazo* in shape, dimension, and distribution. The basal plate of the scale is similer to that of *C. manazo*, but the posterior angle is not so much produced. The scales have mostly four ridges, two central larger and two lateral smaller,

Fig. 2.

Scales of Cynias griseus, ×60.



which do not reach to the posterior end of the posterior arm of the scale. The posterior arm of the scales on the dorsal side of trunk are often slightly tricuspidate. The scales on the ventral side of trunk and also on the two dorsal fins have only two ridges, all other scales are similar to those of *C. manazo*.

The relative dimensions of the scale are much alike those of *C. manazo* but the scales on the tongue are wider than long. The measurments are given as follows:—

TABLE II. Cynias griseus.

	Main body of the scales				Basal plate of the scales					
	Length		Width		Length		Width		Height	
Dorsal side of head ...	26—33	30	22—23	23	21—25	23	27—29	28	11—13	12
„ „ „ abdomen	30—39	35	22—24	23	19—21	20	25—28	26	7—11	9
„ „ „ caudal ped.	43—53	48	27—34	31	27—33	30	37—40	38	13—15	14
Ventral side of head ...	31—39	36	27—35	32	26—34	33	29—15	31	12—16	14
„ „ „ abdomen	31—39	35	19—22	21	15—20	17	22—28	25	13—19	16
„ „ „ tud (c.p.)	33—40	36	21—26	24	20—27	24	26—30	28	11—18	15
1st dorsal fin	19—25	22	15—18	17	9—11	10	13—19	17	7—10	9
2nd dorsal fin	23—31	27	15—19	18	9—13	11	18—20	19	7— 9	8
Terminal portion of C.F.	23—29	26	15—18	17	10—15	12	16—18	17	5— 7	6
Pectoral fin	22—27	25	14—19	17	10—13	11	18—19	18	8—13	10
Ventral fin.....	21—30	27	18—22	20	12—13	13	18—24	20	7—11	9
Anal fin	21—28	24	14—20	16	10—15	12	15—22	18	6—11	8
Tongue	16—22	19	18—26	21	12—21	17	24—31	27	8—11	9

The scales are mostly colourless; but the basal plate of the scales on the dorsal trunk are brightly yellow in colour whereas those of the scales on the ventral trunk are faintly grayish brown.

The structure of the pulpa and the development of anchoring fibers of connective tissue are nearly the same as found in the scales of *C. manazo*.

It may be mentioned that the scales of the present species bear much resemblance to those of *C. manazo*, distinct differences being found in the scales situated on the dorsal side of the trunk and ventral side of caudal peduncle.

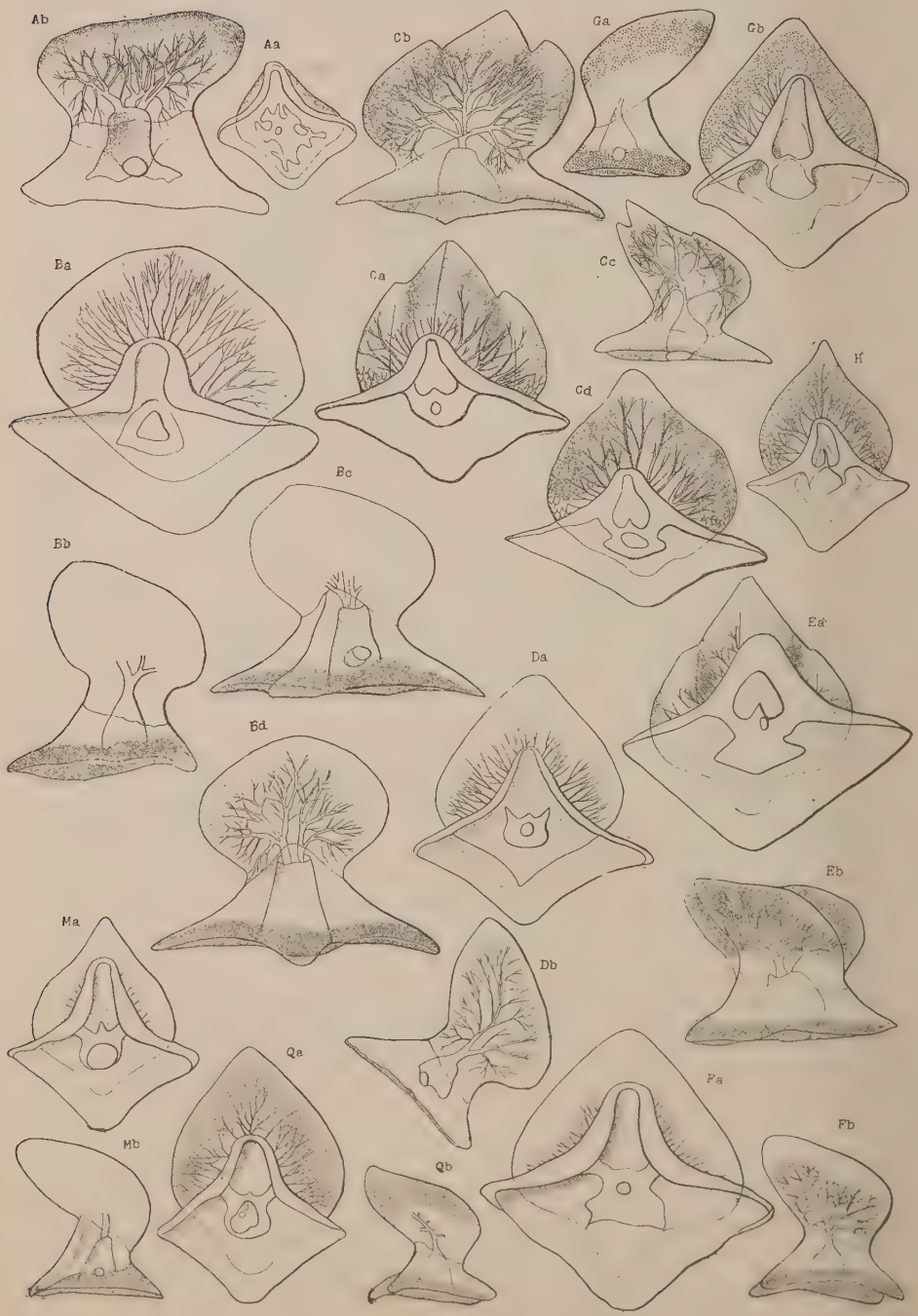
(3) Triakis scyllium M. & H. (Fig. 3).

The specimen measured 100 cm. in length, the width of the scale exceeding 0.7 mm.

The scales of the present species are very large and massive, not so much compactly set on the body surface, rather variable in shape according to the area where they are found, but showing resemblance to those of *C. manazo* and *C. griseus*.

Fig. 3.

Ccales of Triakis scyllium, *Aa*, ×35; all others, ×60.



The lateral arms are greatly swollen, resulting to shorten the posterior arm. The pulpa cavity is very large and thickly branched. The anchoring fibers of connective tisse are very large and give off two postero-lateral branches in all the scales except in those found on both the dorsal and ventral sides of the head.

The scaly sculptures are feebly developed in the proximal portion of the lateral arm of the scales, but these sculptures are quite absent on the scales of the head.

The basal plate is nearly rectangular, posterior and lateral angles being much produced.

The scales on the dorsal side of the body and the ventral fins are dark brown in colour, but those on the ventral side are quite colourless.

There is no scale on the tongue.

Table III gives the dimensions of the scales.

TABLE III. Triakis scyllium.

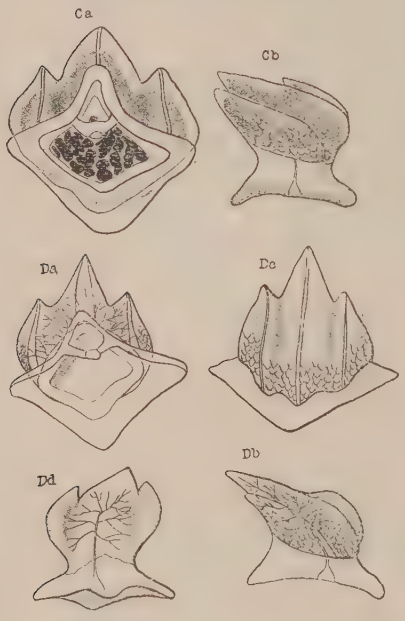
	Main body of the scales				Basal plate of the scales					
	Length		Width		Length		Width		Height	
Dorsal side of head ...	55—60	57	63—77	70	70—72	71	85—91	88	20—25	23
D. s. of abdomen	45—52	49	43—54	47	35—36	36	56—69	61	15—19	17
D. s. of c. p.	55—62	58	47—55	51	44—62	54	61—72	67	15—22	19
Ventral side of head ...	51—55	53	53—56	54	40—46	43	58—67	63	24—34	28
V. s. of abdomen	47—53	50	42—44	43	38—42	40	48—56	52	17—22	19
V. s. of c. p.	41—58	51	39—53	48	39—53	47	47—64	58	16—24	20
1st d. s.	44—57	50	36—44	39	38—45	42	38—45	45	18—25	21
2nd d. s.	38—54	48	30—45	38	28—49	41	34—49	47	14—17	16
Terminal portion of caudal fin	45—55	49	31—41	38	37—42	39	35—46	41	16—19	18
Pectoral fin	45—51	49	33—40	36	35—43	40	36—48	43	17—21	19
V. f.	37—44	41	27—33	30	25—33	30	29—40	35	16—20	18
An. f.	35—44	40	25—37	32	25—34	30	31—44	38	14—18	16

(4) Prionace glauca (Linné). (Fig. 4).

The specimen measured about 2.5 meters in length. I could obtain the scales on the dorsal and ventral sides of the trunk only.

Fig. 4.

Scales of Prionace glauca, ×60.



The scales are very small, measuring less than 0.5 mm. in length.

Generally speaking, the scales have much developed lateral arms, distinctly tricuspidate, ending acutely. Three prominent ridges run longitudinally.

Scaly sculptures are seen on the anterior and lateral arms. The basal plate is nearly rectangular, posterior angle acutely projecting.

Dark pigments are found in the scales on the dorsal side of the trunk, but never in those on the ventral side.

(5) Carcharinus japonicus (T. & S.) (Fig. 5).

The fish measured about one meter in length. The scales are very large and compactly set, some of the scales exceeding 0.7 mm. in width.

Three types of the scales may be distinguished: (1) rectangular or elliptical in outline and wider than long, (2) elongately elliptical, and longer than wide, and (3) head-like in shape. The first type of the scales is found on the trunk and in the buccal cavity, second type on the fins, and third type on the clasper.

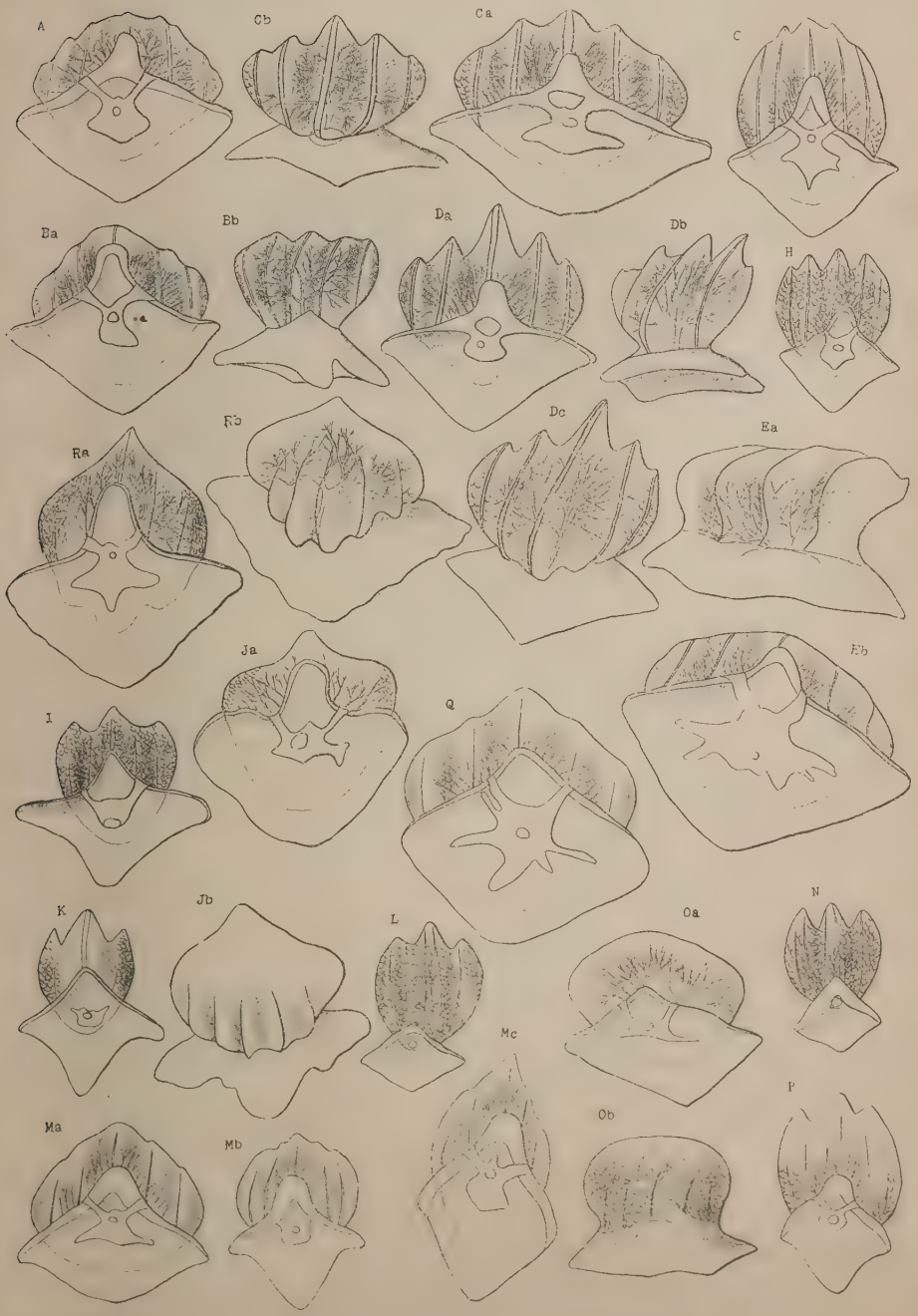
Five ridges are found in all the scales except those on the branchial pouch where they have three ridges. Scaly sculptures are developed in the scales on the fins and in the buccal cavity, covering the main body of the scale, even to the tip of the porsterior arm. But they are scarcely seen in the scales situated on the head and caudal peduncle.

The anchoring fibers of connective tissue are very large, especially so in the scales situated in the distal half of the body.

The dorsal scales are generally faintly grayish yellow in colour but the

Fig. 5.

Scales of Carcharinus japonicus, ×60.



ventral scales are colourless. The basal plates, however, are faintly grayish yellow in all the scales. The measurement is given in Table IV.

TABLE IV. Carcharinus japonicus.

	Main body of the scales				Basal plate of the scales					
	Length		Width		Length		Width		Height.	
	μ									
Dorsal side of head ...	29—33	31	32—40	36	36—43	39	42—48	45	14—20	16
Dorsal side of abdomen	31—38	35	43—56	50	32—36	34	56—68	62	7—11	9
Dorsal side of caudal ped.	42—44	43	60—65	63	46—51	49	71—72	72	17—19	18
Ventral side of head ...	30—34	32	35—39	37	31—34	32	40—43	42	15—19	17
„ „ „ abdomen	35—41	37	32—46	40	28—35	32	39—53	47	14—15	15
„ „ „ caud. ped.	38—46	42	63—73	67	51—58	54	71—83	76	15—22	18
1st dorsal fin	39—46	56	34—42	38	36—24	40	36—47	42		
2nd dorsal fin.....	31—33	32	29—31	30	27—32	30	31—33	32		
Caudal fin	40—49	45	39—56	48	37—46	42	44—59	52		
Pectoral fin	32—48	41	25—34	31	30—44	39	29—37	33		
Ventral fin	23—25	24	17—20	19	15—19	17	15—18	17		
Anal fin	35—40	38	28—32	30	25—33	30	25—31	29	20—12	11
Tongue	38—41	39	34—40	37	36—45	41	44—57	50		
Pharynx.	28—33	31	26—30	28	28—40	35	41—48	44		
Buccal canity	33—40	37	32—41	37	39—45	42	52—61	57		
Gill-arch.....	25—31	27	22—26	24	25—30	28	31—39	34		
Clasper	27—28	27	41—47	44	24—26	25	45—50	43	11—12	11

General considerations.

Two groups may be distinguished among the examined forms of the selachians according to the shape of the scales. The first group comprises two genera, *Cynias* and *Triakis*, and is characterized by having the unbranched posterior arm of the scale. The second includes two genera, *Prionace* and *Carcharinus*, and is characterized by having well differentiated posterior arm

of the main body of the scale. Attention is called to the fact that the above-mentioned two groups of the selachians are characterized by other features which may be tabulated as follows :—

	Group I	Group II
Spiracle	present	absent
Pits in the caudal peduncle	feebly developed or absent	well developed
Teeth	similar on both jaws	different on both jaws
Reproduction	mostly ovo-viviparous	exclusively viviparous

It may be mentioned that *Galeorhinus* and *Galeocerdo* are referable to the first group and *Scoliodon* may be included in the second, although the scale characters have not yet been studied.

These group distinctions, however, do not hold in some forms of this family occurring outside the Japanese waters. But the facts seem to point to the conclusions that the placoid scale serves as a good systematic criterion when taken together with other characters, and that the family Carchariidae is not a compact group and should be divided into several subgroups.

Exponential Decrease of Susceptibility to Anaesthesia with Age in the Water-flea, *Moina macrocopa* Strauss.[1]

By

Arata Terao and Tomozô Tanaka.

(Received March 15th, 1930).

The object of the present paper is to analyze mathematically our data already published in this journal.[2]

First, the velocity of anaesthesia in the water-fleas should be proportional to the ratio of surface area to volume of the body, if other conditions are equal. Second, this ratio is again proportional to the reciprocal of the body length, if the experimental animals are of a geometrically similar shape. Third, *Moina macrocopa* reaches sexual maturity, when reared at a constant temperature of 27° C., two days after hatching and maintains from this

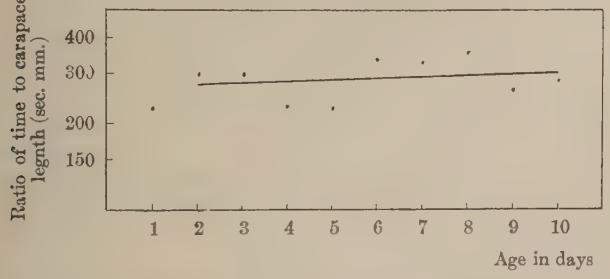


Fig. 1. Showing ratio of time required for anaesthesia (in sec.) to carapace length (in mm.) in relation to age of *Moina* (in days).

stage on a nearly similar shape. Fourth, the carapace length is a rather reliable measure of the body length of our material. Consequently, a series of the ratios of the mean values of time required for anaesthesia to that of

1) Contributions from Zoological Laboratory, Imperial Fisheries Institute, No. 6 (Preliminary Note).

2) A. Terao and T. Tanaka, Anaesthesia of the water-flea, *Moina macrocopa* Strauss, in relation to age. Jour. 25 (1): 13–14. *1 fig.* 1929.

the carapace length of sexually mature age groups should represent susceptibility of the water-flea to anaesthesia in relation to age. It is worth while to note that this series shows a linear relation when plotted on semi-logarithmic paper (Fig. 1). In other words, susceptibility decreases exponentially as age increases in these age groups. Computing the values of the constants by the method of least squares we have

$$y = 266.962e^{.011x}$$

where y represents the ratio of time required for anaesthesia to the carapace length in sec.-mm. units, and x age in days.

Population Growth of the Water-flea, *Moina macrocopa* Strauss, in Relation to the Amount of Culture-medium.[1]

By

Arata Terao and Tomozô Tanaka.

(Received March 15th, 1930).

The water-fleas were reared in vials at a constant temperature of 27°C, as shown in the following tables.

Table I. Equal depth and diameter of the culture-medium.

Amount of culture-medium (c.c.)	5	10	15	20	40	80
Average saturation population per 1 c.c.	24.70	24.50	17.78	20.70	16.54	15.58

Table II. Same diameter and different depths of the culture-medium.

Amount of culture-medium (c.c.)	3	6	12	24
Average saturation population per 1 c.c.	35.50	28.28	24.29	20.96

Table III. Same depth and different diameters of the culture-medium.

Amount of culture-medium (c.c.)	4.70	7.75	13.83	24.50	39.00
Average saturation population per 1 c.c.	16.04	19.68	20.67	19.12	17.22

It is clear that the average saturation population of the water-flea per 1 c.c. increases as the diameter of the culture-medium increases, if we keep the depth constant, and that it decreases as the depth increases.

1) Contributions from Zoological Laboratory, Imperial Fisheries Institute, No. 7 (Preliminary Note).

Therefore,

$$\frac{\partial z}{\partial x} = ay + k_1,$$

$$\frac{\partial z}{\partial y} = -(bx + k_2)$$

where z represents saturation population per unit volume, x depth, y diameter, of the culture-medium, and a, b, k_1, and k_2 constants.

For the constancy of z, we have

$$dz = (ay + k_1)dx - (bx + k_2)dy = 0,$$

$$\frac{dx}{bx + k_2} = \frac{dy}{ay + k_1}.$$

On integration,

$$\frac{1}{b}\log\left(x + \frac{k_2}{b}\right) = \frac{1}{a}\log\left(y + \frac{k_1}{a}\right) + C.$$

Duration of Life of the Water-flea, *Moina macrocopa* Strauss, in Relation to Temperature.[1]

By

Arata Terao and Tomozô Tanaka.

(Received March 15th, 1930).

One individual was put within one hour after hatching in each of vials containing 25 c.c. of culture-medium. The vials were kept in compartments of a Seno-Tauti serial incubator, regulated at 33°, 27°, 21°, 15°, 9°, and 5°C. respectively. Table I summarizes our results.

Table I. Duration of life of *Moina* in relation to temperature.

Number of individuals	133	108	112	115	117	111
Temperature (C)	33°	27°	21°	15°	9°	5°
Average duration of life in days	4.778 ±.067	6.519 ±1.670	9.286 ±.180	14.365 ±.385	10.188 ±.463	4.158 ±.158

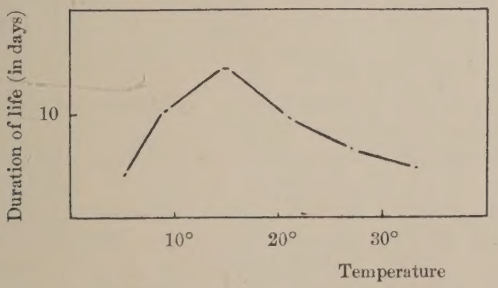


Fig. 1. Showing average duration of life of *Moina macrocopa* at different temperatures.

There is clearly to be seen in Fig. 1 that maximum duration of life of *Moina* takes place at about 15°C.

1) Contributions from Zoological Laboratory, Imperial Fisheries Institute, No. 8 (Preliminary Note).

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